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The crucial role of the neotectonic deformation in landfill site selection: The case study of Avlonas, Attiki, Greece

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ABSTRACT: In order to understand the differentiation of the mechanical properties of the rockunit from place to place of the Avlonas landfill site, the geomorphology, geology, as well as the neotectonic deformation of the site were studied in detail. The study concluded to separate the area in two sub-areas. Thereafter for the purpose of judging to select the sub-area with the more geotechnical advandges to be used as landfill site, all the above mentioned were quantified by using a multi criteria evaluation system. The result was that, although the geoparameters in the two subareas are the same, and inspite the two distinguished subareas are in contact, they present totally different geotechnical characteristics due to the different local neotectonic deformation of brittle type, resulting, the area eastern of Koukistras ravin to have more advandages than the western one.

1 INTRODUCTION

It is well known that critical in determining the strength of a rock mass is the pattern, the number, and the type of discontinuities. Discontinuities may include bedding, schistosity, faults, joints, and cleavage.

Specifically concerning larger rock bodies, it is very important to consider that in higly tectonised areas and, especially in tectonic active areas, with long neotectonic prehistory, the type of neotectonic deformation, in connection to that of the alpine cycle, is very important and is one of the factors controlling the mechanical properties of rocks. Properties of soils and rocks usually vary from place to place and in many cases from point to point at a specific site; however, there also exist cases where properties of soils and rocks may be similar for large areas, under certain circumstances. As far as we know there are no studies neither methodologies have been proposed, to take into account the contribution of the neotectonic deformation to the definition of mechanical properties of the rock mass. Therefore engineering geological mapping is critical. This is particularly true during the planning stage. Geological mapping is enhanced when combined with neotectonic, geomorphological and hydrogeological mapping.

The case of the Avlona landfill site, is a characteristic example of differentiation of the mechanical properties of the rockunit from place to place during the neotectonic period.For the above mentioned purposes the Geomorphology, Geology, Neotectonics were studied in details.

The small basin in which the proposed by the authorities landfill site belongs, is located approximatelly 3 km western of Avlonas village, at the northern margin of Parnis Mt. (Northern Attiki). The shape of the basin is similar to an ellipsoid, with the big axis striking WNW-ESE. From the tectonic point of view it consists a second order neotectonic graben, which has been filled in with neogene lacustrine deposits.

2 GEOMORPHOLOGY

As already has been mentioned, the proposed Avlonas landfill site is located in a basin elongated parallel to an axis striking WNW-ESE. This basin constitutes a part of the hydrological basin of Koukistras torrent, which in its turn is draining the major part of northern Parnis Mt..

The major part of the western, and eastren boundary of the Avlonas basin watershed coincides with the watershed of the Koukistras basin, striking N-S. Intensive linear erosion is observed southern and northern of the study area.

The Koukistras ravin, which is a 5^{th} order stream of Assopos river system, crosses the basin from

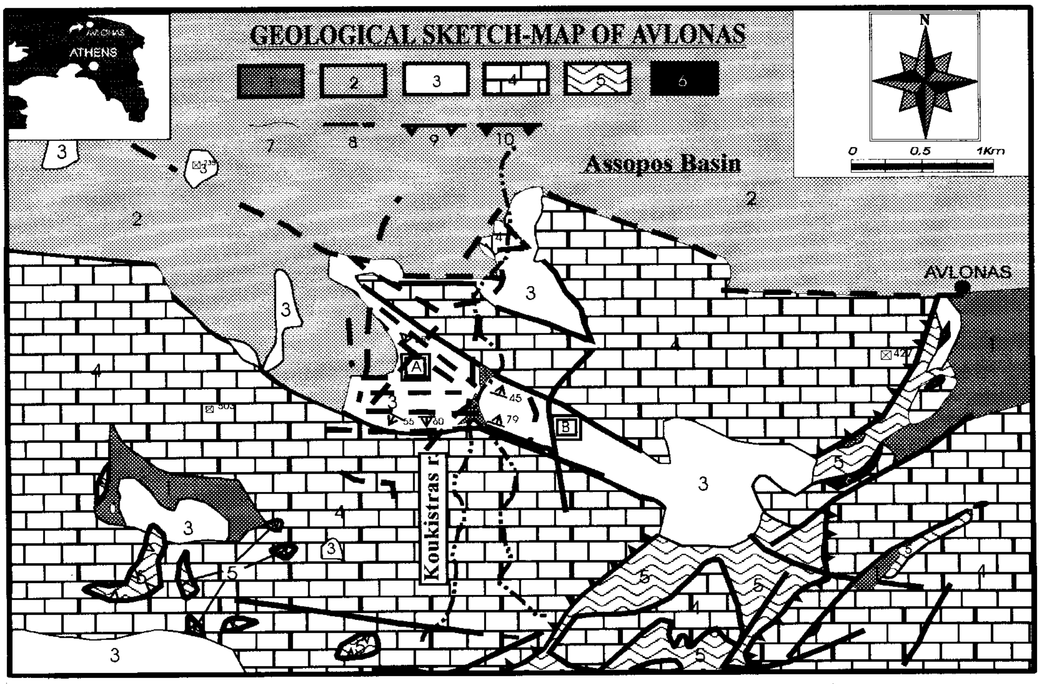

Fig. 1. Geological sketch-map of Avlonas 1: Holocene deposits, 2: Quaternary deposits, 3: Neogene lacustrine sediments, 4: Mesozoic carbonates, 5: Ophiolites, 6: Iron ore occurrences, 7:Geological boundary, 8:Fault, 9:Imbricate fault, 10:Thrust fault

TABLE I

WESTERN SUB-AREA	EASTERN SUB-AREA
The morphological gradient is generally $<10^0$ whereas locally reaches 15^0. In sites with higher altitudes the morphological gradient reaches the 25^0.	The morphological gradient varies from whereas locally reaches the 11^0. In sites with higher altitudes the morphological gradient reaches the
The dip direction of the neogene strata is towards south. The dip is genarally 45^0, but it increases at the southern part where it is $> 60^0$.	The dip direction of the neogene strata is towards north. The dip varies 35^0-45^0, and it reach the southern part.
There are many faults striking E-W and WNW-ESE. The eastern limit of them is the Koukistras ravin.	There are very few faults (only 2) striking N-S.
Northern slopes: Both the morphological gradient and the neogene strata dip southwards resulting in the locally occurance of landslides, especially at locations crossed by faults.	Landslides have not been observed.
From the kinematic point of view during the late neotectonic period, the area seems to rotate around an horizontal axis of E-W direction towards south.	From the kinematic point of view during the late neotectonic period, the area seems to rotate around an horizontal axis of E-W direction towards north.

south to north and divides the basin in two sub-areas, the western (A) and the eastern (B) one (Fig. 1). At the eastern sub-area (B) there is no well formed bed of ravin, while at the western sub-area (A) there are some remnants of formed bed ravin.

At the eastern sub-area (B) the morphological gradient fluctuates from 3^0 to 5^0 and only locally it reaches the 11^0. At the westren sub-area (A) the morphological gradient is relatively higher fluctuating from 3^0 to 7^0 and locally reaches the 25^0 in two cases. Thus, comparing from the morphological gradient point of view, the two sub-areas, the eastern sub area (B) seems to have better characteristics than the western one (A).

3 GEOLOGY

At the landfill site area, based on the detail mapping in scale 1/5.000, the following geological formations can be distinguished (from the younger to the older):

3.1 Post alpine formations

Alluvial deposits: They are Holocene, fluvial, deposits consisting mainly of pebbles and cobles, which come from the carbonatic rocks of the basement. Its thickness varies from few centimeters to some meters.

Continental deposits: At the major area of Avlonas landfill site and mainly western and northern of it, continental deposits occur in the form of fans. Based on morphological and sedimentological criteria, they can be distinguished in different periods of deposition, although in several cases many succesive and lateral transitions of the older to the younger fan generations are observed, resulting the formation of a non-divided fan zone. These deposits consist of alternations of loose conglomerates, sandstones, silts, and clays. The conglomerates consit of pebbles coming from the carbonates, basic and ultra basic rocks, hornstones (radiolarites) as well as neogene marly limestones. Their thickness vary from some tens of centimeters to a few decades of meters. These deposits form very characteristic geomorphological surfaces, which have been changed due to later uplifting movements of the area. Intensive linear erosion is observed in the streams, which are developed on these deposits, especially at the area northern of the study area.

Lacustrine deposits: They consist of alternations of marly limestones, marls, and sandstones, whereas at the upper part of the formation, unconsolidated conglomerates occur with well rounded pebbels. The big axis of the pebbles is no more than 8 cm, and they come from the carbonatic rocks of the basement. Their age is of Late Miocene whereas their thickness, locally, is more than 200 m. (METTOS, 1992). At the study area the thickness locally should be higher than 60 m., and anyway it is not constant because these sediments have been deposited on a well formed paleoreleif of the alpine basement.

3.2 Alpine formations

Carbonatic rocks: They are light-gray and some times dark-gray, thick bedded or without bedding crystalline, dolomitic limestones and dolomites, which are intensively fractured and karstified. It is very difficult to estimate their thickness, the visible thicness is 500 m. Their age vary from M. Triassic to L. Jurassic.

Ophiolites: They consist of serpentinized and weathered ultra basic and basic rocks. These ophiolites have been overthrusted on the triassic-jurassic carbonates. Maximum visible thickness 200 m.

4 TECTONICS - NEOTECTONICS

The deformation of the major area has taken place in two periods, the alpine and the post-alpine or neotectonic. Folds in different scales, reverse faults and thrust faults, as well as faults, are the main alpine tectonic structures. The alpine deformation has affected only the alpine formations. Brittle type of deformation (fault zones, faults) are the main tectonic structures, which characterize the neotectonic period. The neotectonic deformation has affected both alpine and post-alpine formations.

The neotectonic deformation has formed the post alpine basins (**Fig. 1**). The neotectonic structure of the major area includes several small and two large basins: (i) the closed Thiva basin north of the study area (ii) the Assopos basin, drained to the Southern Euboic Gulf, east of Avlonas. In our case the interest is focused to the Assopos basin, as the study area is located at its southern margin.

The creation of the Assopos basin should have started in Miocene times as the sediments which have filled in the basin is of Late Miocene age.The evolution of the basin has been changed during Quaternary, the time period in which the whole area has been uplifted. This uplift results linear and surficial erosion

The morphotectonic structure of the Assopos river basin is the result of normal faults striking E-W, which stepwise have subsided the areas located northern relatively to that located southern to Avlonas.

The southwestren part of the Assopos graben is controlled by fault zone striking E-W, whereas the southeastern part (study area) is contrtolled by two fault zones striking WNW-ESE, named Avlonas and Oropos - Agioi Apostoloi. The total vertical throw of these fault zones is estimated more than 500m for the time period Pliocene - present time (PAPANIKOLAOU et al., 1988).

The ladfill site area represents a smaller order neotectonic graben at the transition neotectonic zone between the major neotectonic horst of Parnis Mt. to the south and the major neotectonic graben of Assopos to the north. More specifically the study area is crossed by faults striking mainly E-W and WNW-ESE, of which are small in length. Karstification of the carbonates and the marly limestones has been developed along these faults.

Koukistras ravin coincides with a fault zone, which seems to have played a crucial role to the differentiation, from neotectonic fault pattern point of view, of the two sub-areas eastern and western of it, as they are described in the following.

Concerning the fault density, there is a remarkable differentiation in the number of faults which cut the neogene deposits at each sub-area. Hence, there are many faults at the western sub-area, striking E-W and WNW-ESE, both terminating at Koukistras ravin, without passing to the eastern sub-area, in which there are very few faults srtiking N-S. Consequently, the western sub-area is more fractured by faults than the eastern one.

At the western subarea, the bedding of the neogene deposits dips constantly towards south, with a dip of 45^0. This dip becomes greater ($>60^0$) very close to the southern margin of the graben, whereas the bedding dip constant towards south. On the contrary, at the eastern subarea, the bedding of the neogene deposits dips towards north, with a dip of 35^0-45^0. This dip reaches 80^0 very close to the southern margin of the graben and always the bedding is constantly northwards. From the kinematic point of view, the above mentioned for the two areas can be interpretated as two blocks rotating around an E-W horizontal axis, but with opposite trends, the western southwards, and the eastern northwards.

5 DISCUSSION - CONCLUSIONS

Summerizing all the above mentioned the TABLE I was prepared, in order to compare easier the characteristics of the two sub-areas, which were created by brittle deformation during the neotectonic period.

For the purpose of selecting the subarea with the more geotechnical advantages to be used as landfill site, all the above mentioned were quantified by using a multi criteria evaluation sytem. The result was that, although the lithostratigraphy in the two sub-areas is the same, and inspite that the two distinguished subareas are in contact, they present totally different geotechnical characteristics due to the different local neotectonic deformation of brittle type, resulting, the area eastern of Koukistras ravin to have more advantages than the western one.

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